UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF CIRCULARLY POLARIZED RECTENNA WITH HARMONIC REJECTION CAPABILITY AT 2.45 GHZ FOR MICROWAVE ENERGY TRANSFER

SHARIF AHMED QASEM AHMED

MASTER OF SCIENCE IN ELECTRONIC ENGINEERING

2017

Faculty of Electronic and Computer Engineering

DESIGN OF CIRCULARLY POLARIZED RECTENNA WITH HARMONIC REJECTION CAPABILITY AT 2.45 GHZ FOR MICROWAVE ENERGY TRANSFER

Sharif Ahmed Qasem Ahmed

Master of Science in Electronic Engineering

2017

DESIGN OF CIRCULARLY POLARIZED RECTENNA WITH HARMONIC REJECTION CAPABILITY AT 2.45 GHZ FOR MICROWAVE ENERGY TRANSFER

SHARIF AHMED QASEM AHMED

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science in Electronic Engineering

Faculty of Electronic and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this thesis entitled “Design of Circularly Polarized Rectenna with Harmonic Rejection Capability at 2.45 GHz for Microwave Energy Transfer” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Sharif Ahmed Qasem Ahmed

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering

Signature :……...

Supervisor Name : Prof. Dato' Dr. Mohd Nor Bin Husain

Date :……...

DEDICATION

To my beloved mother and father

ABSTRACT

Nowadays, with the fast development in wireless devices, microwave energy transfer in which energy is transmitted from one point to another without wires, becomes more vital. There are many applications in which microwave energy transfer technology can be utilized such as smart healthcare, environmental monitoring, and home automation. Microwave energy transfer has the advantages of easy communication and lower cost compared to traditional transmission mediums. A rectifying antenna or rectenna which consists of receiving antenna, rectifier, matching network, and output DC filter, is an important element in microwave energy transfer. The antenna receives RF signals that are converted from alternative current (AC) into usable direct current (DC) by the rectifying circuit. Rectifying diodes have nonlinear behavior which generates harmonics and degrades RF-to-DC conversion efficiency of the rectenna. Harmonic rejection filter is used to suppress these harmonics. However, adding harmonic rejection filter increases the size and cost of the rectenna. Antennas with harmonic rejection is used to replace the harmonic rejection filter. However, the proposed antennas have a low gain which degrades rectenna conversion efficiency. To increase the amount of collected RF signals, circular polarization, dual-band and broadband operation are adopted but these techniques increase the size and design complexity. This thesis proposed a rectenna design with harmonics rejection and circular polarization at 2.45 GHz to enhance the RF-DC conversion efficiency. The harmonic rejection capability is achieved using triangular aperture coupling slot. The circular polarization property is achieved with a single feed line which reduces the size and design complexity. The aperture coupled antenna is simulated with an air gap to enhance the gain, using Computer Simulation Technology (CST). The voltage doubler rectifier is simulated with a fast switching HSMS286B Schottky diode, using Advance Design System (ADS). The fabrication process is carried out using a low-cost 4.4 permittivity FR-4 substrate. The antenna can reject harmonics up to 10 GHz with -50 dB return loss, 7 dB gain, 1.5 dB axial ratio and 40.8% axial ratio bandwidth. The doubler rectifier with radial stub filter can provide output DC voltage higher than 7 V. The measured RF-to-DC conversion efficiency of the integrated rectenna is 76.84%. at an input power of 20 dBm. The proposed rectenna has the advantages of harmonic rejection, circular polarization, high gain and low cost which make it a suitable candidate for microwave energy transfer.

ABSTRAK

Pada masa kini, dengan perkembangan pantas dalam peranti tanpa wayar, pemindahan tenaga gelombang mikro di mana tenaga dihantar dari satu titik ke titik yang lain tanpa menggunakan wayar, menjadi sangat penting. Terdapat banyak aplikasi di mana teknologi pemindahan tenaga gelombang mikro boleh digunakan seperti penjagaan kesihatan pintar, pemantauan alam sekitar dan automasi rumah. Pemindahan tenaga gelombang mikro mempunyai kelebihan terhadap komunikasi yang mudah dan kos yang lebih rendah berbanding dengan medium penghantaran tradisional. Sebuah antena penerusan atau "rectenna" yang terdiri daripada antenna penerima, penerus, rangkaian yang hampir sama, dan penapis DC keluaran, adalah elemen penting dalam pemindahan tenaga gelombang mikro. Antena itu menerima isyarat RF yang telah ditukarkan dari arus alternatif (AC) ke dalam arus terus (DC) agar boleh digunakan oleh litar penerusan itu. Diod penerusan mempunyai tingkah laku tidak linear yang mana menjana harmonik dan merendahkan kecekapan penukaran RF-DC "rectenna". Penapis penolakan harmonik telah digunakan untuk menyekat harmonik itu. Walau bagaimanapun, penambahan penapis penolakan harmonik meningkatkan saiz dan kos "rectenna" itu. Antena dengan penolakan harmonik digunakan untuk menggantikan penapis penolakan harmonik. Walau bagaimanapun, antena yang dicadangkan mempunyai dapatan yang rendah yang mana merendahkan kecekapan penukaran "rectenna". Untuk meningkatkan jumlah pengumpulan isyarat RF, polarisasi bulat, dua jalur dan operasi jalur lebar digunakan tetapi teknik-teknik ini meningkatkan saiz dan kerumitan reka bentuk. Thesis ini mencadangkan reka bentuk "rectenna" dengan penolakan harmonik dan polarisasi bulat pada 2.45 GHz untuk meningkatkn kecekapan penukaran RF-DC. Keupayaan penolakan harmonik dapat dicapai menggunakan slot segitiga "aperture coupled". Ciri-ciri polarisasi bulat dapat dicapai dengan satu garis suapan yang mana mengurangkan saiz dan kerumitan reka bentuk. Bukaan terganding antena disimulasi dengan jurang udara untuk meningkatkan dapatan, dengan menggunakan Teknologi Simulasi Komputer (CST). Voltan pendua penerus telah disimulasi dengan pensuisan pantas HSMS286B Schottky Diod, menggunakan Rekabentuk Sistem Kehadapan (ADS). Proses fabrikasi dijalankan menggunakan FR-4 substrat kos rendah dengan 4.4 ketelusan. Antena ini boleh menolak harmonik sehingga 10 GHz dengan -50 dB kehilangan balik, 7 dB dapatan, 1.5 nisbah paksi dB dan 40.8% nisbah paksi jalur lebar. Penerus pendua dengan penapis puntung jejarian boleh memberikan keluaran DC voltan lebih tinggi daripada 7V. Pengukuran kecekapan penukaran RF-DC "rectenna" bersepadu adalah 76.84% pada kuasa masukan 20 dBm. "Rectenna" yang dicadangkan mempunyai kelebihan penolakan harmonik, polarisasi bulat, dapatan yang tinggi dan kos rendah yang menjadikannya calon yang sesuai digunakan untuk pemindahan tenaga gelombang mikro.

ACKNOWLEDGEMENTS

First and foremost,i would like to praise to Allah, the almighty for giving me a little strength and granting me the capability to do my master research and eventually succeed to complete my thesis as required. I would like to warmly thank my father and mother for their great support and encourage thoughout my research work. Throughout my master reseach project, there have been support, guidance and assistance of several people which helped me to finish this research work and write my thesis to appears in its current form. Therefore, its an oppertunatiy to thank and appreciate these people's great efforts.

I would like to take this opportunity to express my greatest gratitude to my supportive supervisors, Prof. Dato' Dr. Mohd Nor Bin Husain and Associate Professor Dr. Zahriladha for their insightful knowledge and valuable assistance throughout this research project.

I would like to express my thanks to all lecturers and technicians, from Faculty of Electronics and Computer Engineering (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM), for their time and efforts that contributed to my achievement. I would also like to thank UTeM Zamalah Scheme for their encouragement and financial support throughout this project.

Thanks and appreciation go to my fellow Ph.D. students in Makmal Pasca Siswazah laboratory, Ahmed, Sam, Ariffin, Rammah, and Amyrul for their assisstance and being a good friends.

To all my colleagues and friends, Nas, Ammar and Zaimah, i would like to express my thanks for their support thoughout my master research project. Lastly, thank you to everyone who suporrted me directly or indirectly to the crucial parts of realization of this research project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

CST	-	Computer Simulation Technology
ADS	-	Advanced Design System
DUT	-	Device Under Test
RFEH	-	Radio Frequency Energy Harvesting
MET	-	Microwave Energy Transfer
WPT	-	Wireless Power Transfer
RF	-	Radio Frequency
ACAS	-	Aperture Coupled Antenna
AR	-	Axial Ratio
EM	-	Electromagnetic
VNA	-	Vector Network Analyzer